

Onboard Processing and Autonomous Operations on the IPEX Cubesat

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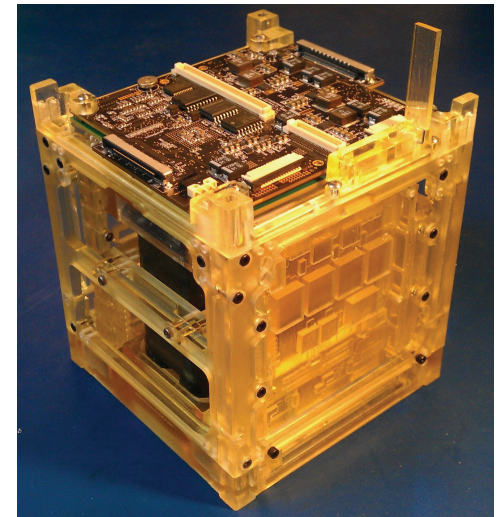
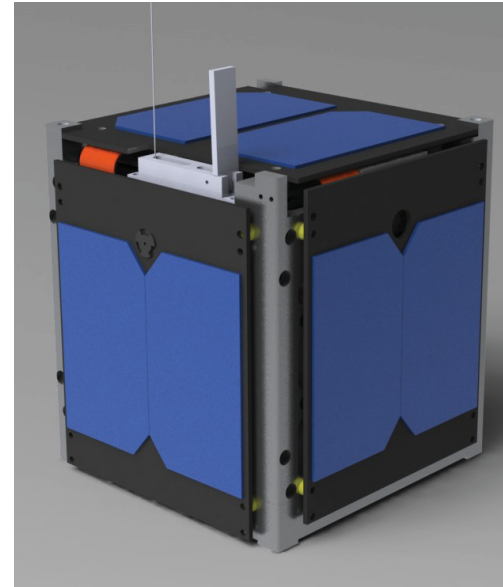
Portions of this work were carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Background

- IPEX is a 1u Cubesat sponsored by NASA Earth Science Technology Office (ESTO)
- Goals
 - Flight validate high performance flight computing (Spacecube Mini / GSFC)
 - Flight validate onboard instrument data processing and product generation software (JPL for HysplRI)
 - Flight validate autonomous operations for instrument processing (JPL)
 - Enhance NASA outreach and University ties (Cal Poly SLO)
 - Cal Poly builds, integrates, operates IPEX cubesat
 - Launch expected in late 2013 (4/2013 launch integration)

Cal Poly SLO spacecraft

- 1u cubesat
- Passively stabilized
 - fixed magnets
- Cal Poly Motherboard
 - 400 MHz Atmel
 - 128 MB RAM
 - 512 MB Flash
 - Micro SD card slot
 - Linux OS

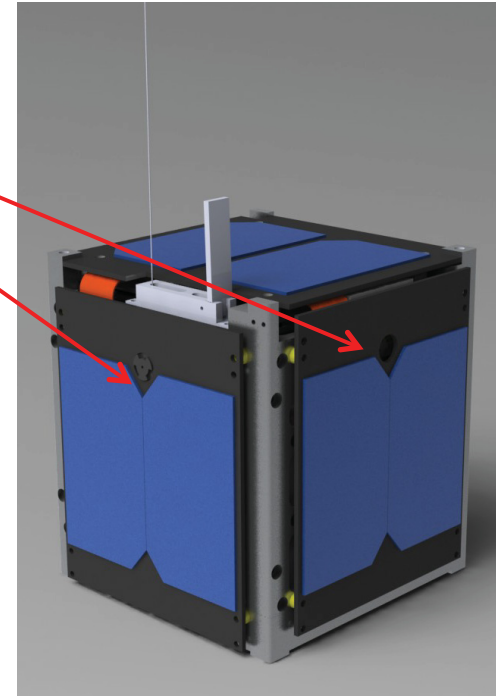


rapid
prototype

Camera

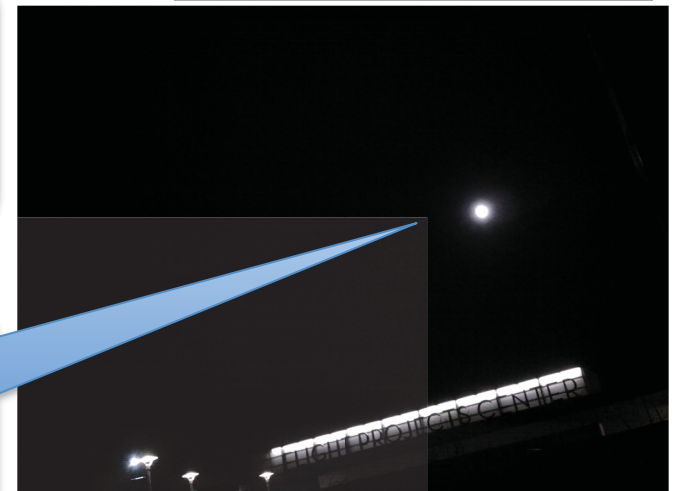
- 4 x Omnivision OV3642
- Camera Specifications
- Focal Length (f): 4mm
- Integration Time (t_{int}): 67ms
- Pixel Diameter (d_{pixel}): 1.75um
- 3 Megapixels
- Instantaneous Field of View (IFOV)
- $IFOV = 2\arctan(d_{\text{pixel}}/2f)$
- IFOV = 0.025 degrees

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Cameras



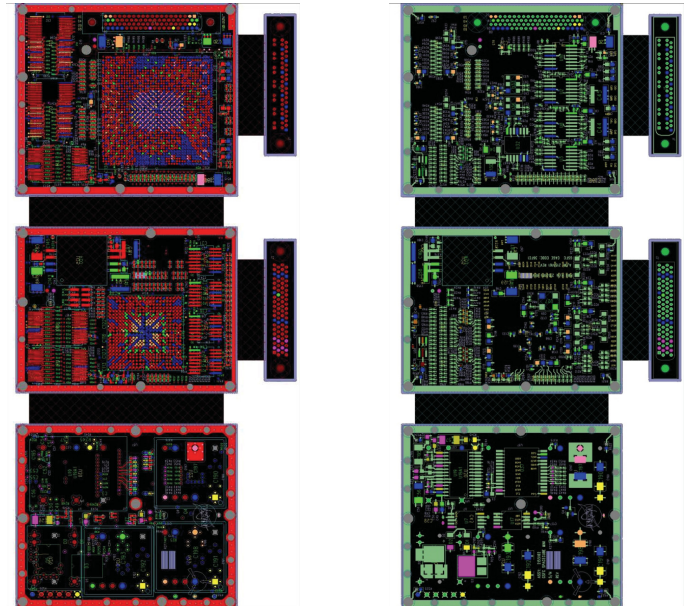
Balloon image,
same sensor
family, same
manufacturer

Image of moon
at night with
flight model
camera



Onboard Computing – SpaceCube Mini

- Uses Xilinx Virtex-5 FX130T
 - 2 X PPC 440 32-bit processors (non-rad hardened version)
 - Aeroflex UT6325 Eclipse FPGA (130M gates)
 - 2 x 256MB DDR RAM
 - 3 x 32Gb NAND Flash
 - Runs scLinux
-
- Provided by GSFC
 - ~5% duty cycle due to power (10W)



Onboard Instrument Processing on IPEX

- IPEX will utilize the SC Mini FPGA and PPC to:
 - Demonstrate onboard image correction and bad data rejection
 - image filtering while tumbling
 - Onboard product generation
 - Using both Omnivision data and Hyperspectral data loaded at launch
 - Stretch goal of processing streaming data
 - 1 image per second, tracking Earth and other objects

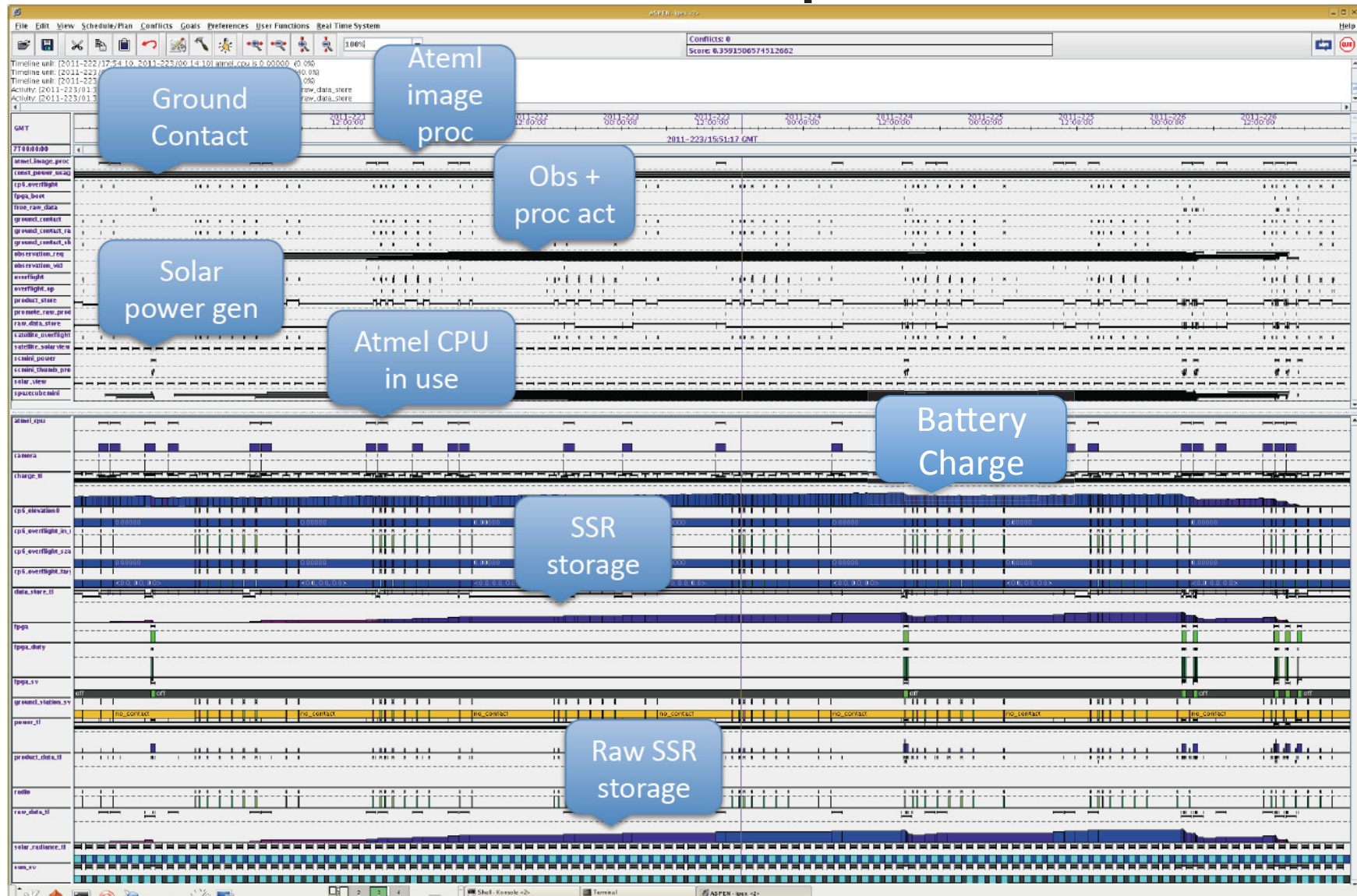
Autonomous Operations on IPEX

- IPEX will fly the CASPER onboard mission planning software (on Atmel) to:
 - Manage resources onboard
 - Take actions based on image analysis
 - Image based on image and product compression
 - Re-image based on detection of features/events in images
 - CASPER flown on Earth Observing One 2004-present as part of Autonomous Sciencecraft

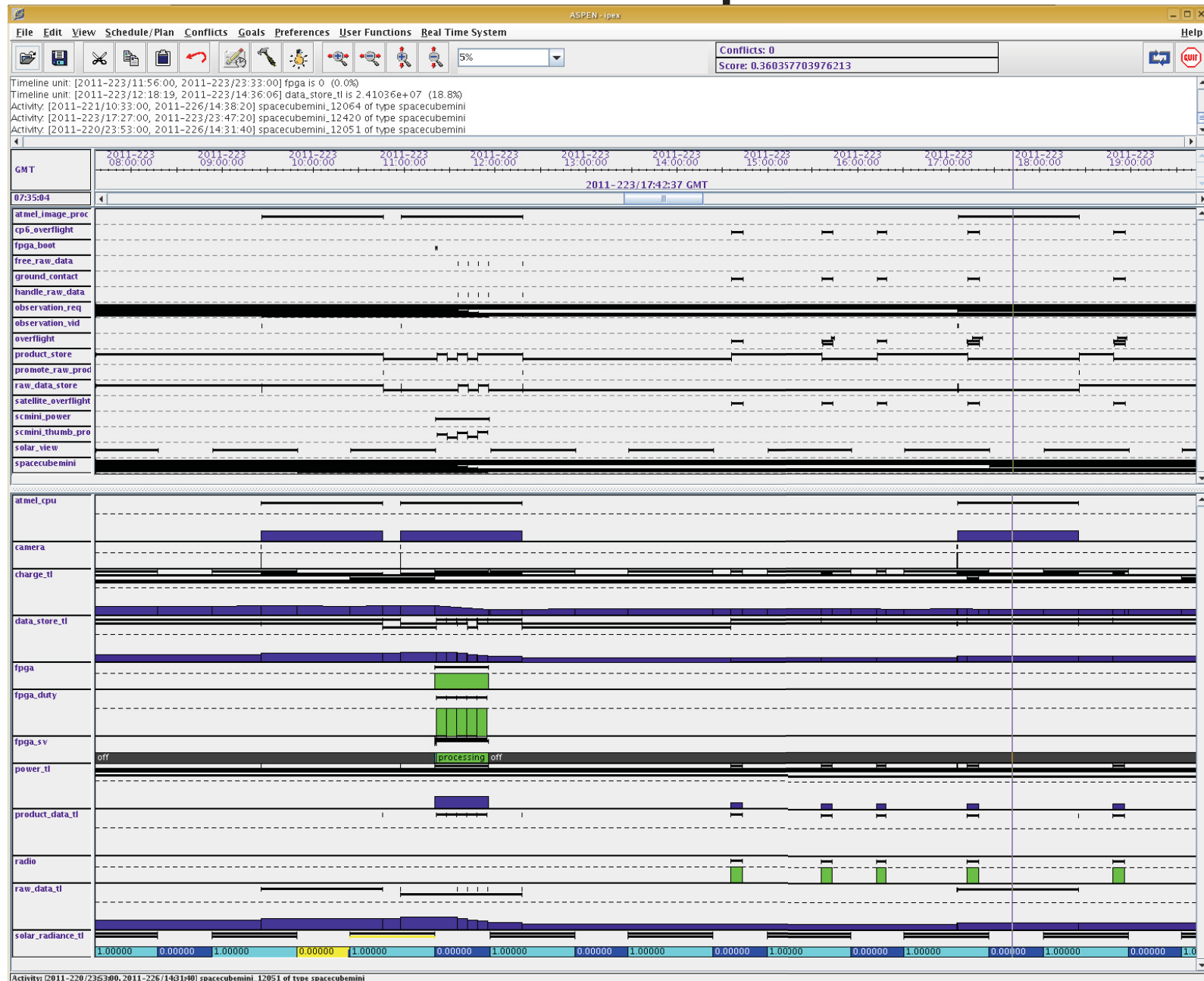
Autonomous Operations

- Baseline Schedule created on ground using ASPEN
 - Ground-contact schedule of non-overlapping contact windows
 - prefer longest contacts, maintain schedule of alternates
 - Eclipse schedule
 - Observation Activities
 - Subsequent processing activities: quick filter, full processing, comparison of results, maybe reprocessing if comparison fails
- Constraints:
 - SpaceCube Mini processing occurs only during eclipse (thermal)
 - power: ~10Watt – 15Watt (!)
 - Prefer to pack these activities to minimize boot time
 - Data storage: raw images, processed images, summary products < flash storage capacity (e.g. 4GB)
 - Energy capacity of battery: ~50 Whr
 - Solar generation: <~1.5 Watt

Autonomous Operations



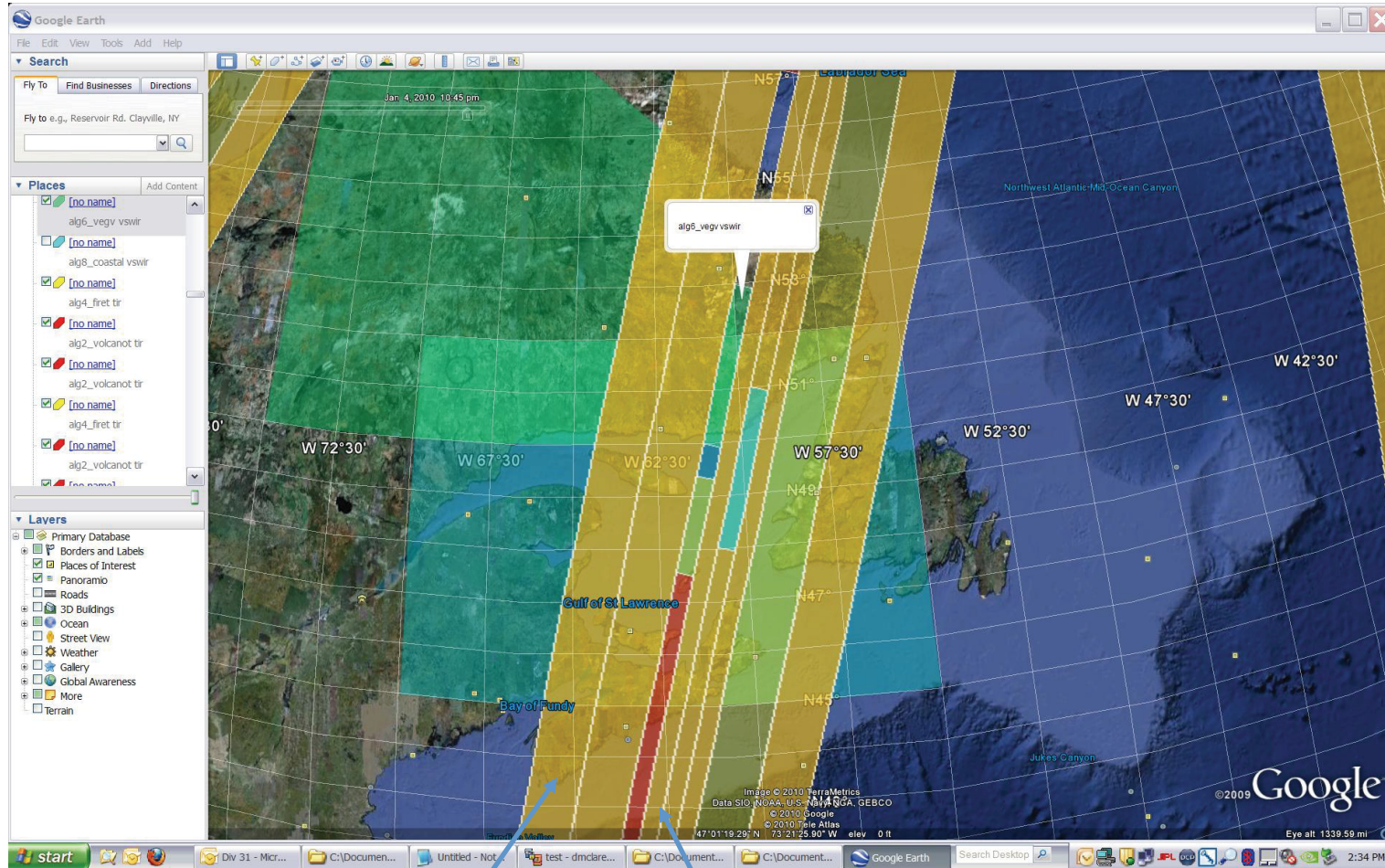
Autonomous Operations



Autonomous Operations for HyspIRI IPM

- HyspIRI Mission concept is a mission under study which includes a VSWIR hyperspectral imager and TIR Thermal infrared imager
- HyspIRI is studying a heritage Direct Broadcast concept Intelligent Payload Module which will process the $\sim 800 \times 10^6$ bits/second raw data stream into $\sim 10 \times 10^6$ bits/second direct broadcast data stream
- IPEX will demonstrate automated planning and processing of the data as maturation of the prototype HyspIRI IPM operations system
 - Users specify regions of interest, products, and priorities in Google Earth TM
 - System automatically creates priority based plans for onboard processing and downlink

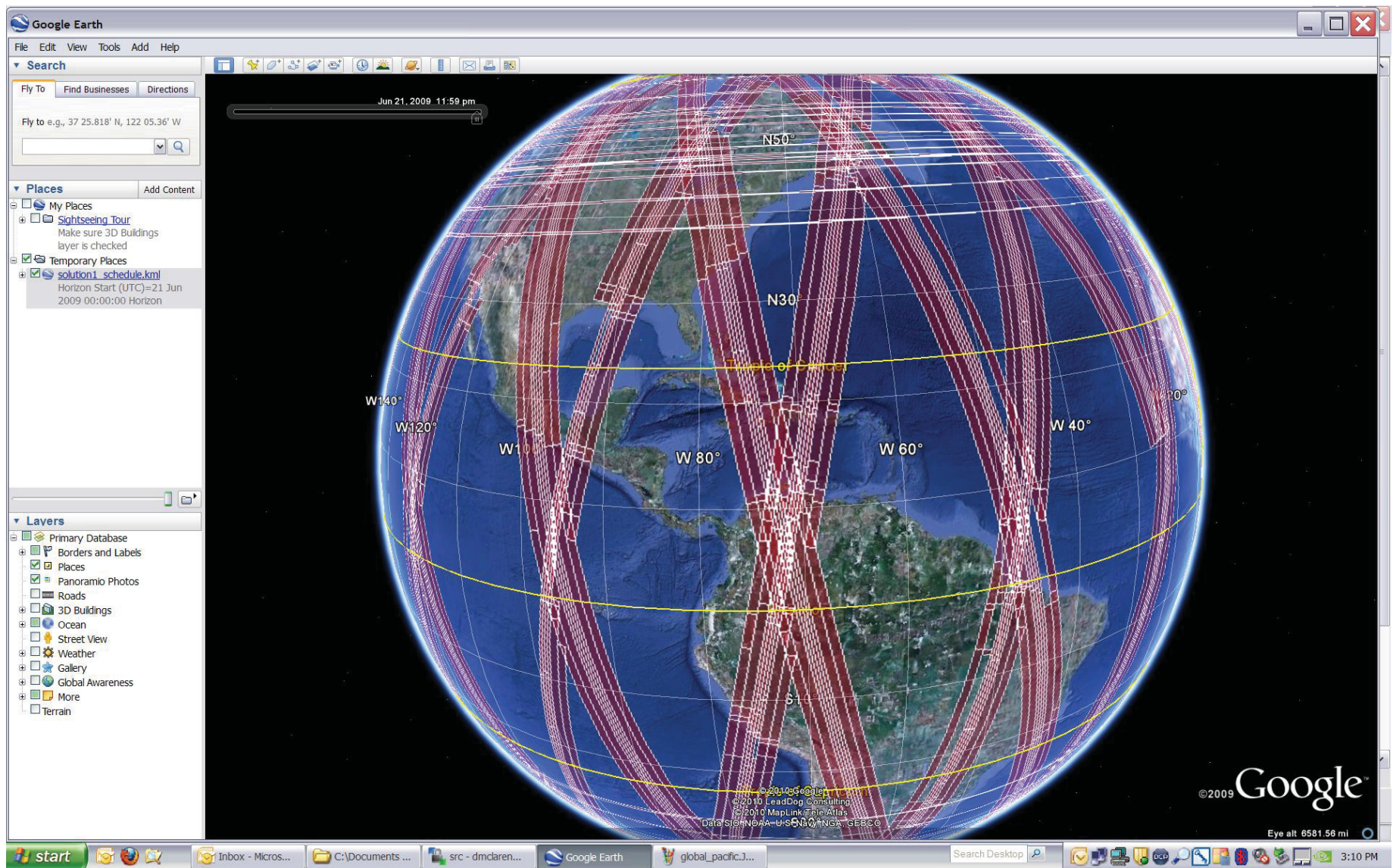
Instrument Swaths



4 x 112.5 km wide –TIR only

4 x 37.5 km wide – VSWIR + TIR

Sample Plans



Other JPL Cubesat Concepts

- Several additional cubesat concepts (not ESTO funded) that may use same cubesat bus
 - Space Situational Awareness (w. AFRL)
 - Onboard Computing Demonstration of Opera/Maestro 7x7 multicore processor
 - Onboard autonomy and instrument processing demonstrations with gumstix processors and gumstix clusters